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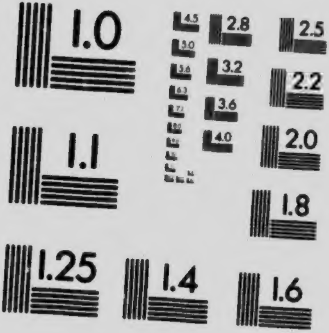

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PAPERS FROM THE PHYSICAL LABORATORIES

No. 66: THE ESTIMATION OF THE HELIUM CONTENT OF MIXTURES OF GASES BY THE USE OF A KATHAROMETER, BY V. F. MURRAY

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The Estimation of the Helium Content of Mixtures of Gases by the Use of a Katharometer[1]

By V. F. MURRAY, M.A., B.Sc.

Presented by PROFESSOR J. C. MCLENNAN, F.R.S.C.

(Read May Meeting, 1919.)

INTRODUCTION

The katharometer instruments dealt with in this paper were designed for use with mixtures of hydrogen and air. In view of the use of helium in airships it seemed desirable to investigate whether such instruments could be utilised for mixtures of helium with air, helium with oxygen, and helium with nitrogen.

Since the katharometer is based upon the thermal conductivity of a gas mixture, it would be anticipated that the instrument, at least in the case of high percentage mixtures of helium with the gases mentioned, could be employed. Values for the thermal conductivity of hydrogen at O°C have been given as $K \times 10^{-6} = 327$ (Winkelmann); 397 (Eucken)[2]; 416·5 (Weber)[3]; while that for helium at O°C has been found to be $K \times 10^{-6} = 336$ (Eucken); 338·6 (Schwarze); 343·8 (Weber)[3]. Thus the thermal conductivities of helium and hydrogen are of the same order.

On experiment it was found that the various instruments responded when helium mixtures were used, and they were therefore calibrated for mixtures made with this gas and air, oxygen or nitrogen.

PRINCIPLE OF THE KATHAROMETER

Dr. G. A. Shakespear has supplied us with information on the design and details of the instruments dealt with in this paper and we are indebted to him for the greater portion of the [illegible] of the description which follows.

In a katharometer the measurement depends upon the cooling of a platinum spiral on exposure to the gas mixture which is being tested. This spiral, carried on a copper frame, is mounted in a copper cylinder pierced at the end and with three small orifices to admit the gas mixture in question. This sensitive element, which is used in conjunction with a pointer indicator (See Plate II) or galvanometer, is called a Katharometer[1] or an explorer, and is illustrated in Plate I.

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[1] Communicated by Professor J. C. McLennan, F.R.S., by permission of the Admiralty.

[2] Landolt-Börnstein Tab.

[3] Weber. Annal. d. Physik. Bd. 54, 1917.

We are indebted to the Cambridge Scientific Instrument Co., Ltd., the makers of the instruments, for permission to reproduce Plates I and II, and also Fig. I.

The electrical bridge arrangment used with the katharometer is shown in Fig. 1. In this diagram, S and E are switches, D a 2-volt accumulator, C two sliding resistances for rough and fine adjustment

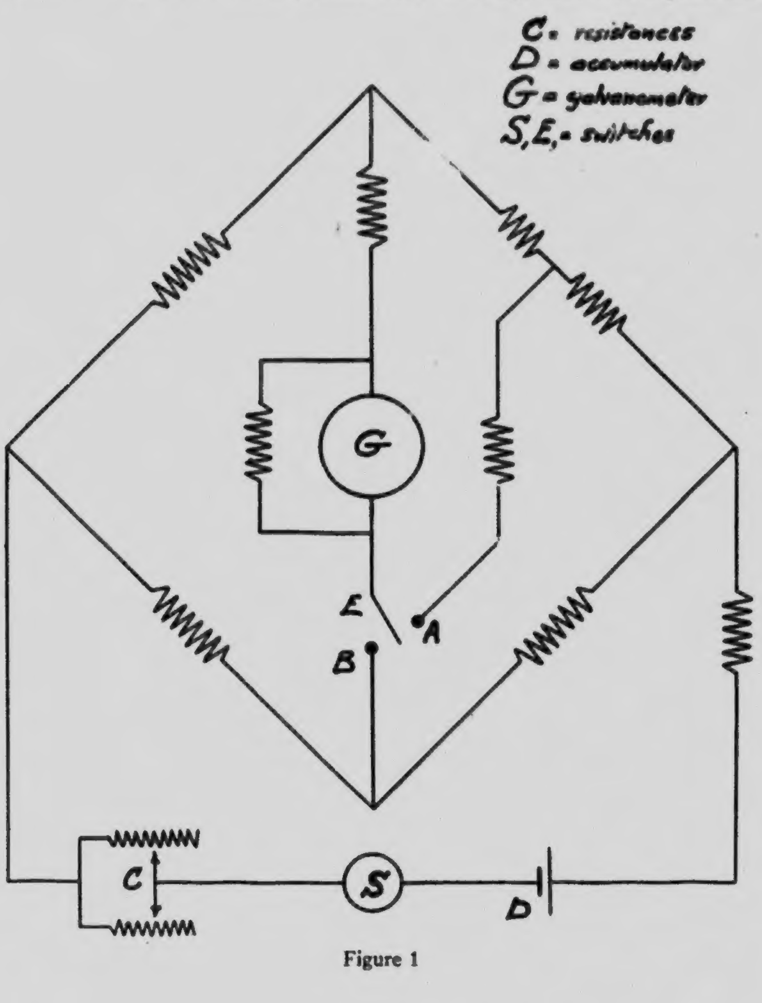

Figure 1

and G a galvanometer. In one arm of bridge there is a comparison protected spiral corresponding to the exposed spiral previously mentioned. In the case of detection of hydrogen in air the exposed and protected spirals are symmetrical and of equal resistance; in the case of detection of air in hydrogen the two spirals are unsymmetrical, and the exposed spiral about one-quarter the resistance of the protected spiral.

When a reading is to be made, switch S is closed and switch E turned to A—the "calibration" position. By means of the resistance at C, the deflection of the indicator is adjusted to a calibration deflection. In this way the current is standardized. Switch E is then turned to B—the "on" position, and the indicator read.

INSTRUMENTS CALIBRATED

The instruments calibrated were:

1. Shakespear Hydrogen Purity Meter No. 35944.
2. Detail Explorer No. 39273 with Indicator No 37868. (100–70% scale).
3. Detail Explorer No. 39272 with Indicator No. 37868. (0–20% scale).
4. Permeameter Explorer No. 39275 with Tinsley Galvanometer No. 5753.

With the exception of the mirror galvonometer, made by H. Tinsley & Co., the instruments were manufactured by the Cambridge Scientific Instrument Co., Ltd.

EXPERIMENTAL APPARATUS

The general arrangement used in the calibration work is shown diagrammatically in Fig. 2.

Gold-leaf filter-tubes were placed on each side of the sensitive gas cell to act as a protection against mercury vapour. The gas mixture on leaving the mercury aspirator set passed through a phosphorus pentoxide drying-tube and gold-leaf filter to the gas chamber. On leaving the chamber the gas passed through a gold-leaf filter, over a mercury-trap and mercury manometer to the mercury-pump which was used to create a flow of gas when required. If desired, a sample of the gas mixture could be pumped off and collected over mercury as indicated in the figure.

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[1] Shakespear. Advisory Committee for Aeronautics. A new Permeability Tester for Balloon Fabrics. Feb., 1917.

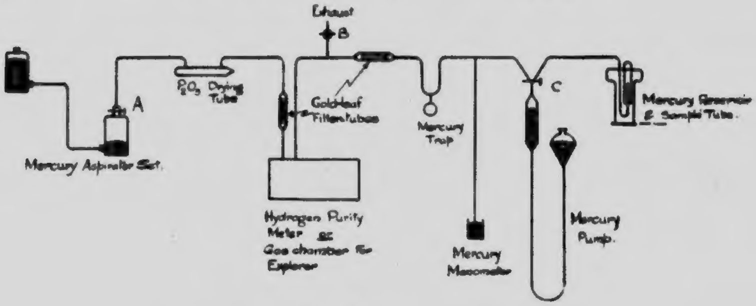

FIG. 2.
DIAGRAMMATIC SKETCH OF APPARATUS USED IN CALIBRATION

PROCEDURE

The apparatus between taps A and C (the volume of which was about 250 ccs.) was exhausted through tap B by a Fleuss pump. This procedure was adopted in order to economise in pure helium, as the amount available at the date of the calibration work was small. Tap B being closed, the gas mixture was slowly admitted at A till the pressure was atmospheric as shown by the manometer. Readings were then taken by the katharometer and also when a slow flow was created by slightly opening tap C.

PER CENT. COMPOSITION OF MIXTURES USED

Two methods were employed to determine the percentage of helium in the mixtures:

1. For high percentages (85–100% helium) the mixture was made approximately by volume, and a sample taken for analysis after passing through the apparatus.
2. For low percentages (0–30% helium) the mixture was made exactly by volume.

The pure helium was prepared from high grade impure gas by passing through cocoanut charcoal at the temperature of liquid oxygen, and was stored in glass gas-tubes over mercury till required.

The analysis referred to in 1 was made by measuring the contraction in volume of a sample after absorption by cocoanut charcoal at the temperature of liquid oxygen. A correction of 0.2 cc. per 18 cc. residual volume was made to allow for the absorption of helium itself by charcoal—a figure obtained for the analysis apparatus employed.

CALIBRATION OF SHAKESPEAR HYDROGEN PURITY METER

This meter is a field instrument designed for measuring the purity of hydrogen in balloons. The indicator readings were from 75–100 with subdivisions of 0·25 per cent.

Mixtures were made of (*a*) helium and oxygen, (*b*) helium and nitrogen, (*c*) helium and air, (*d*) helium, oxygen and nitrogen.

The oxygen for (*a*) was prepared from potassium permanganate in the usual manner; the nitrogen for (*b*) from sodium nitrite and ammonium chloride with a purifying train of red-hot copper, potassium hydroxide, sulphuric acid and phosphorus pentoxide.

The results obtained are plotted in Fig. 3 as percentage helium against instrument reading, the various mixtures being distinguished according to the legend.

This calibration was carried out at room temperature about 16°C.

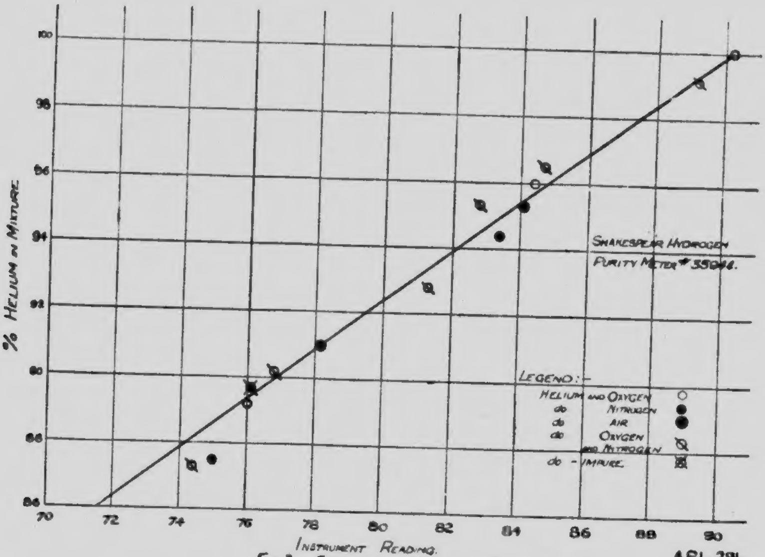

Fig 3. Shakespear Hydrogen Purity Meter.

A straight line has been drawn from which the variations are slight, and according to this line

% Helium = ·7537 × instrument reading + 32·1

Thus if the instrument indicates 82, the corresponding percentage helium = ·753 × 82 + 32·1 = 93·8, which can be read direct from Fig. 3.

Calibration of Indicator with Explorer No. 39273

For purposes of calibration the explorer was screwed into a brass chamber. The inside dimensions of this cylindrical chamber were 1⅞ inches diameter and 1⅜ inches high. Inlet and outlet tubes for the mixture under examination were provided, diametrically opposed,

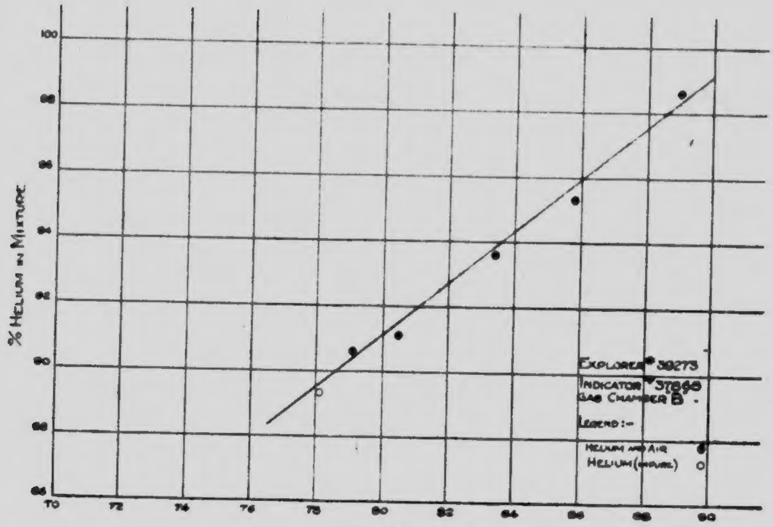

Fig. 4. Indicator with 100-70% Hydrogen Explorer

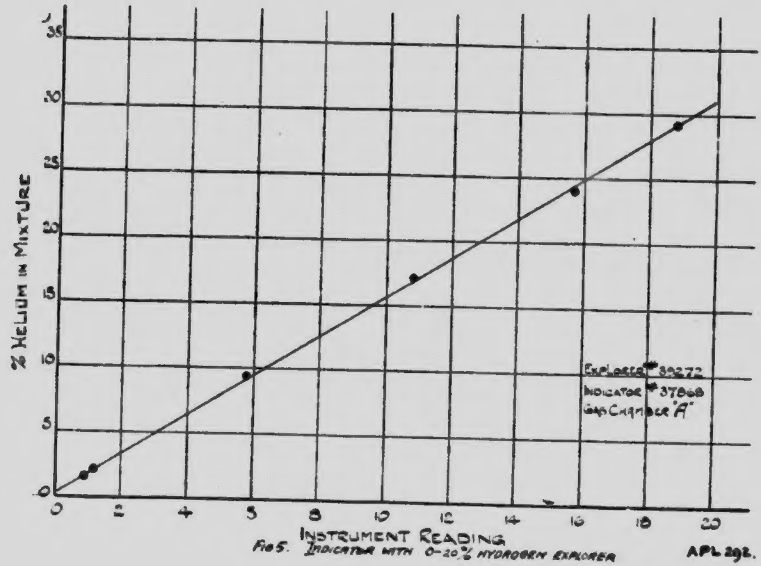

Fig 5. Indicator with 0-20% Hydrogen Explorer

1 inch from the bottom of the chamber and ⅛ inch inside diameter. The explorer was screwed in up to the shoulder and the junction made tight with Chatterton's Compound.

Mixtures of helium and air only were used in this case and the procedure was as previously outlined for the Purity Meter.

The results at room temperature of about 16°C are given in Fig. 4.

According to the straight line drawn in the figure

$$\% \text{ Helium} = \cdot 799 \text{ Instrument Reading} + 27 \cdot 2$$

Thus, if the instrument indicates 82, the corresponding percentage Helium $= \cdot 799 \times 82 + 27 \cdot 2 = 92 \cdot 7$, which can be read direct from Fig. 4.

CALIBRATION OF INDICATOR WITH EXPLORER No. 39272

This explorer was calibrated with mixtures of helium and air only at a temperature of about 15·5°C.

Mixtures were made up by volume from dry helium and dry air; and the percentage calculated.

The results are plotted in Fig. 5, from which it is evident that

$$\% \text{ Helium} = 1 \cdot 56 \times \text{Instrument Reading.}$$

CALIBRATION OF PERMEAMETER EXPLORER No. 39275

This explorer was used in conjunction with a reflecting galvanometer, Tinsley, No. 5753, N. P. L. 39016.

The total scale deflection at 1 metre distance was 500 mms., the scale being divided in mms.

The deflection for 1% Hydrogen in air was given by the Cambridge Scientific Instrument Co., Ltd. as 259 mms.

The explorer was calibrated for

1. Hydrogen-air mixtures;
2. Helium-air mixtures

at 15·5°C, the mixtures being made by volume.

Percentages of hydrogen are plotted against scale deflection in mms. in Fig. 6; and percentages helium against scale deflection in Fig. 7.

The deflection for 1% helium in air was taken from the straight line drawn in Fig. 7 as 165 mms. at 15·5°C.

From Figs. 6 and 7 it is evident that % Helium = 1·57 × Hydrogen percentage for the same scale deflection; or in other words, more helium than hydrogen has to be present to produce the same movement of the spot of light.

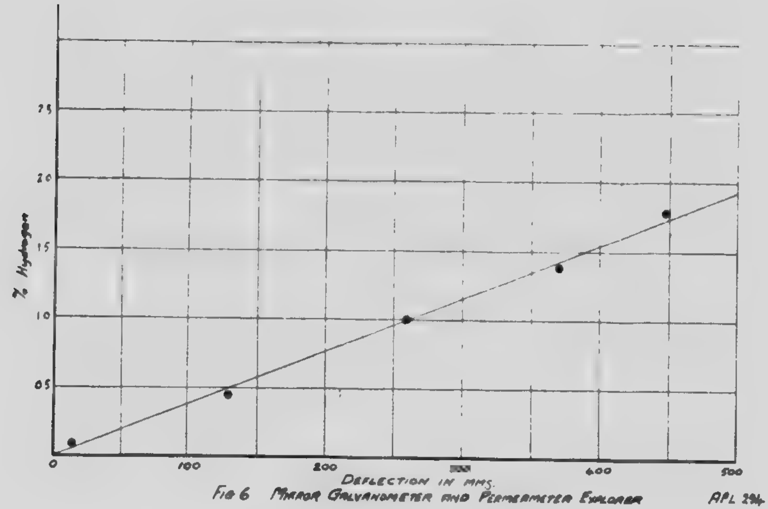

Fig 6 Mirror Galvanometer and Permeameter Explorer APL 294

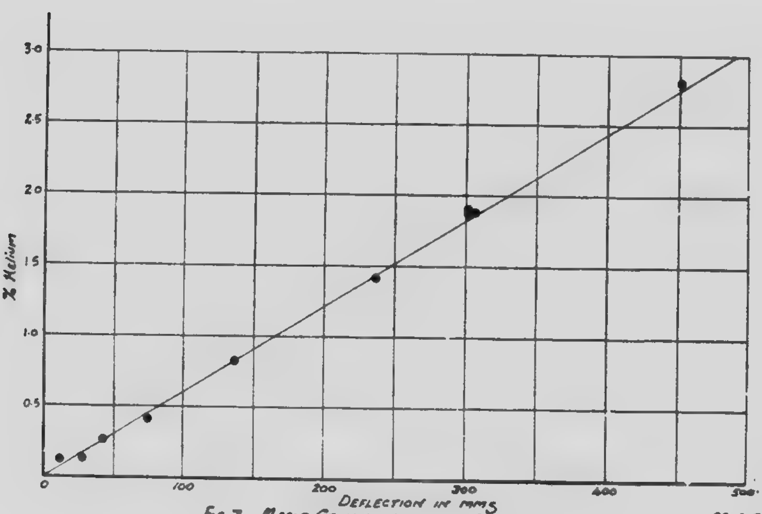

Fig. 7. Mirror Galvanometer and Permeameter Explorer. APL.295

SUMMARY

The Shakespear Hydrogen Purity Meter, high and low percentage hydrogen explorers and a Shakespear Permeameter Explorer have been calibrated for use with helium.

Graphs are given by means of which indicator readings can be converted into percentages of helium.

It was found:

(*a*) that with the Shakespear Hydrogen Purity Meter with helium-air, oxygen or nitrogen mixtures about 89–100% helium could be read.

(*b*) That with 70–100% hydrogen explorer about 84–100% helium could be read.

(*c*) That with a 0–20% hydrogen explorer about 0–30% helium could be read.

(*d*) That the permeameter explorer gave 165 mm. deflection at 1 mm. distance for 1% helium at about 15·5°C.

In concluding, we have to acknowledge indebtedness to Dr. G. A. Shakespear for information on the design of the katharometer, and to the Cambridge Scientific Instrument Co., Ltd., for permission to reproduce Plates I and II, and Fig. 1.

This calibration work was carried out at the Admiralty Physical Laboratory under the direction of Professor J. C. McLennan, F.R.S., Scientific Advisor to the British Admiralty.

South Kensington,

15th April, 1919.

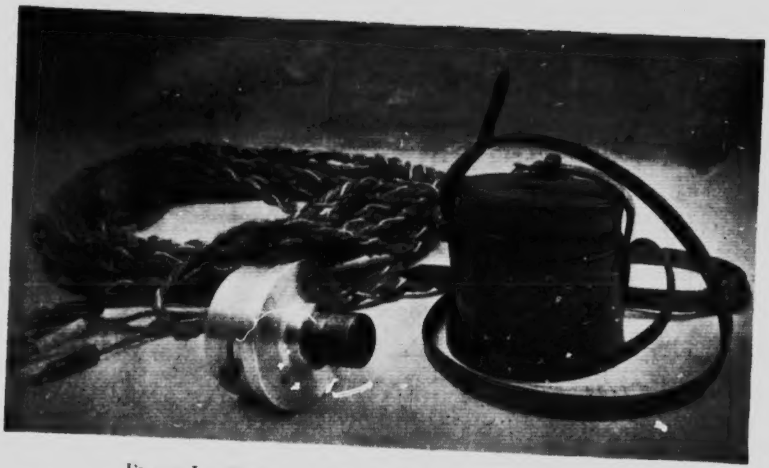

PLATE I.—Shakespear Detail Ball on Fabric Explorer.

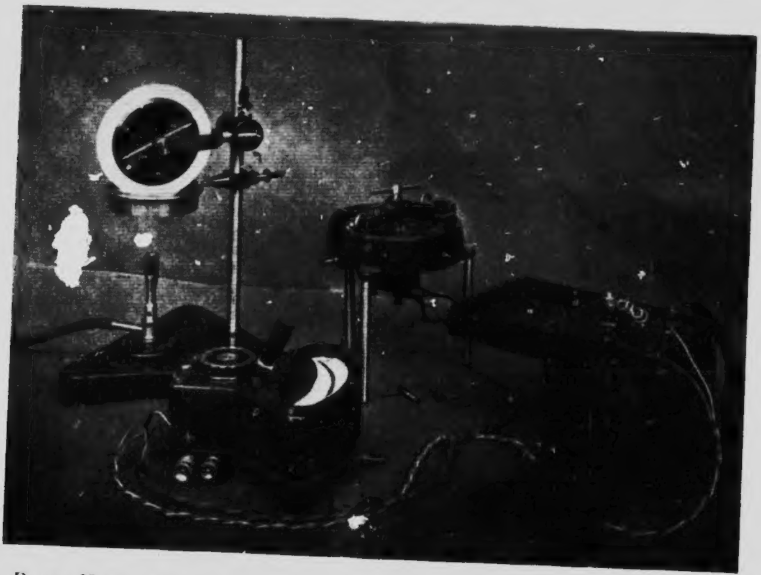

PLATE II.—Indicator, resistances and accumulator (permeameter and dipper.)

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